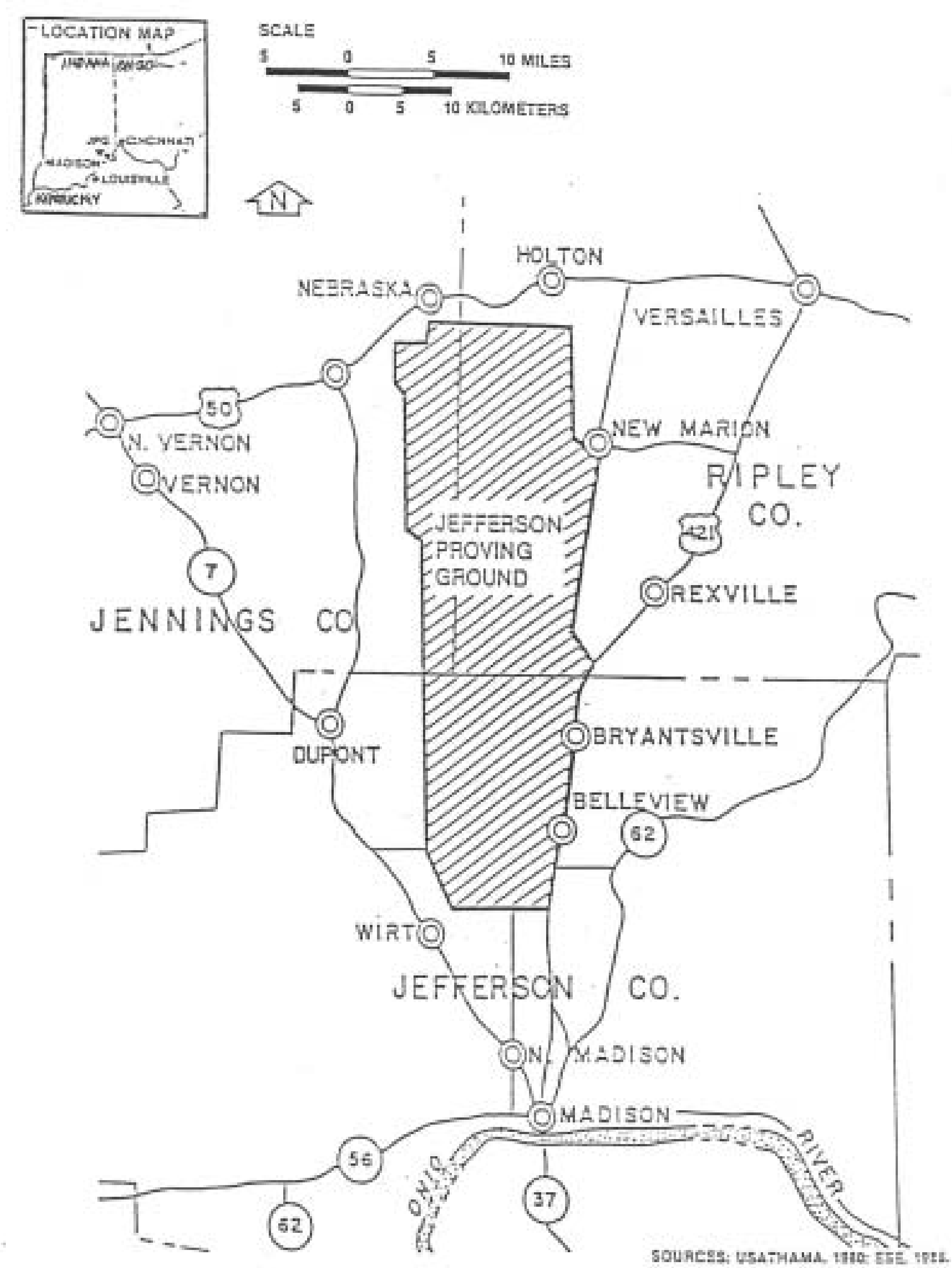
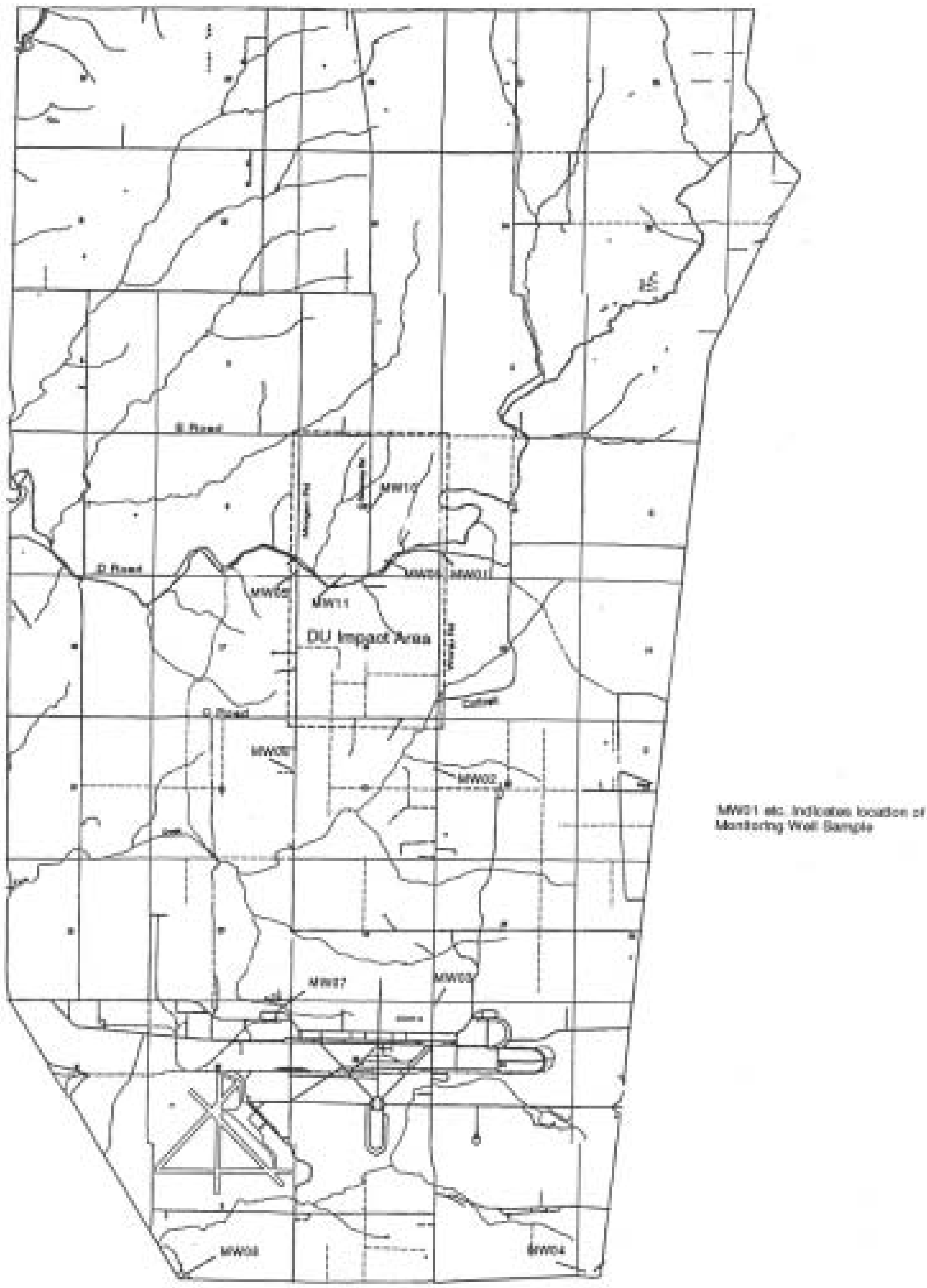
APPENDIX C
MAPS AND DIAGRAMS

(NOTE: More maps and diagrams may be found in the individual reference documents).

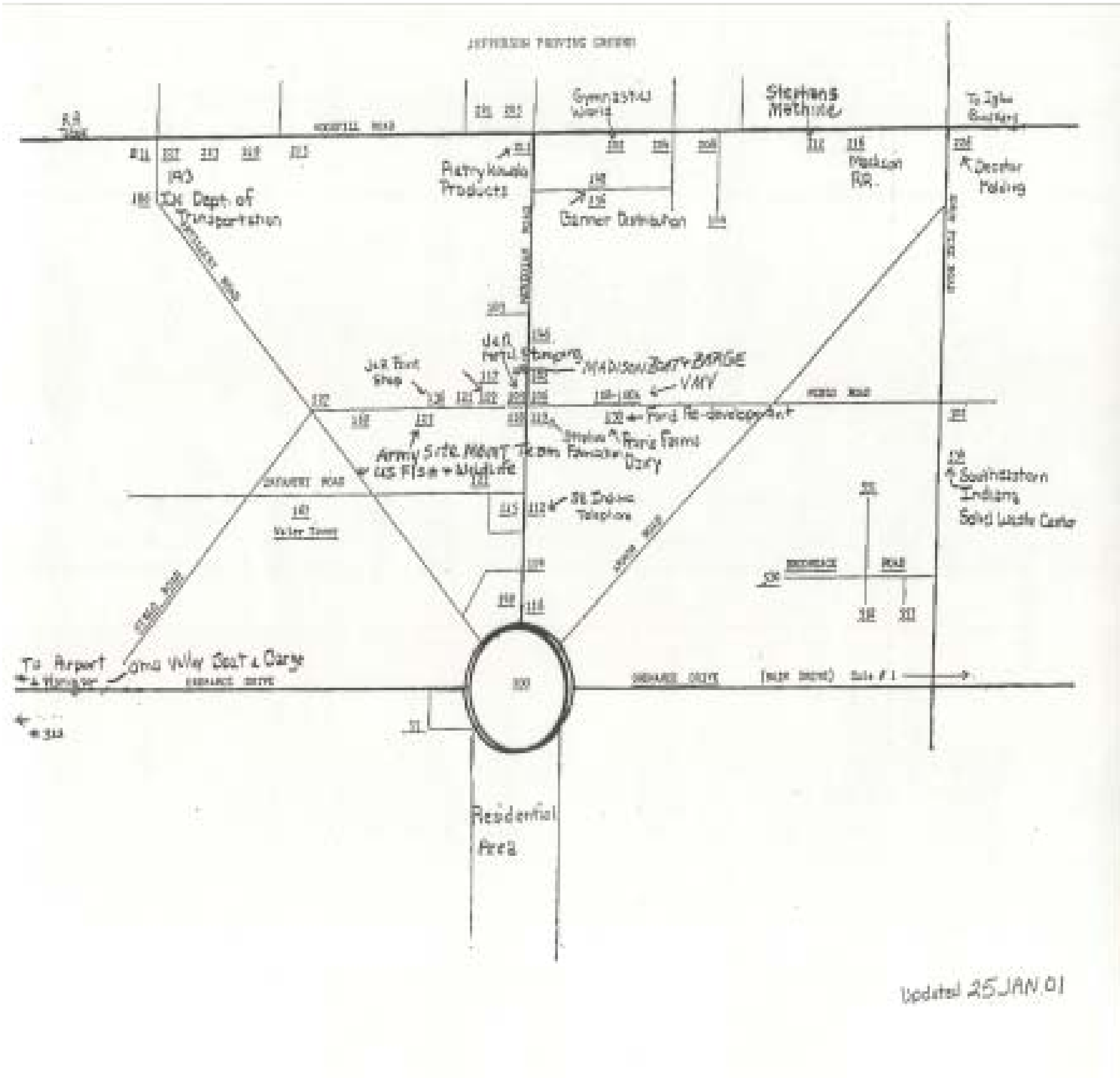
MAP 1, Location Map



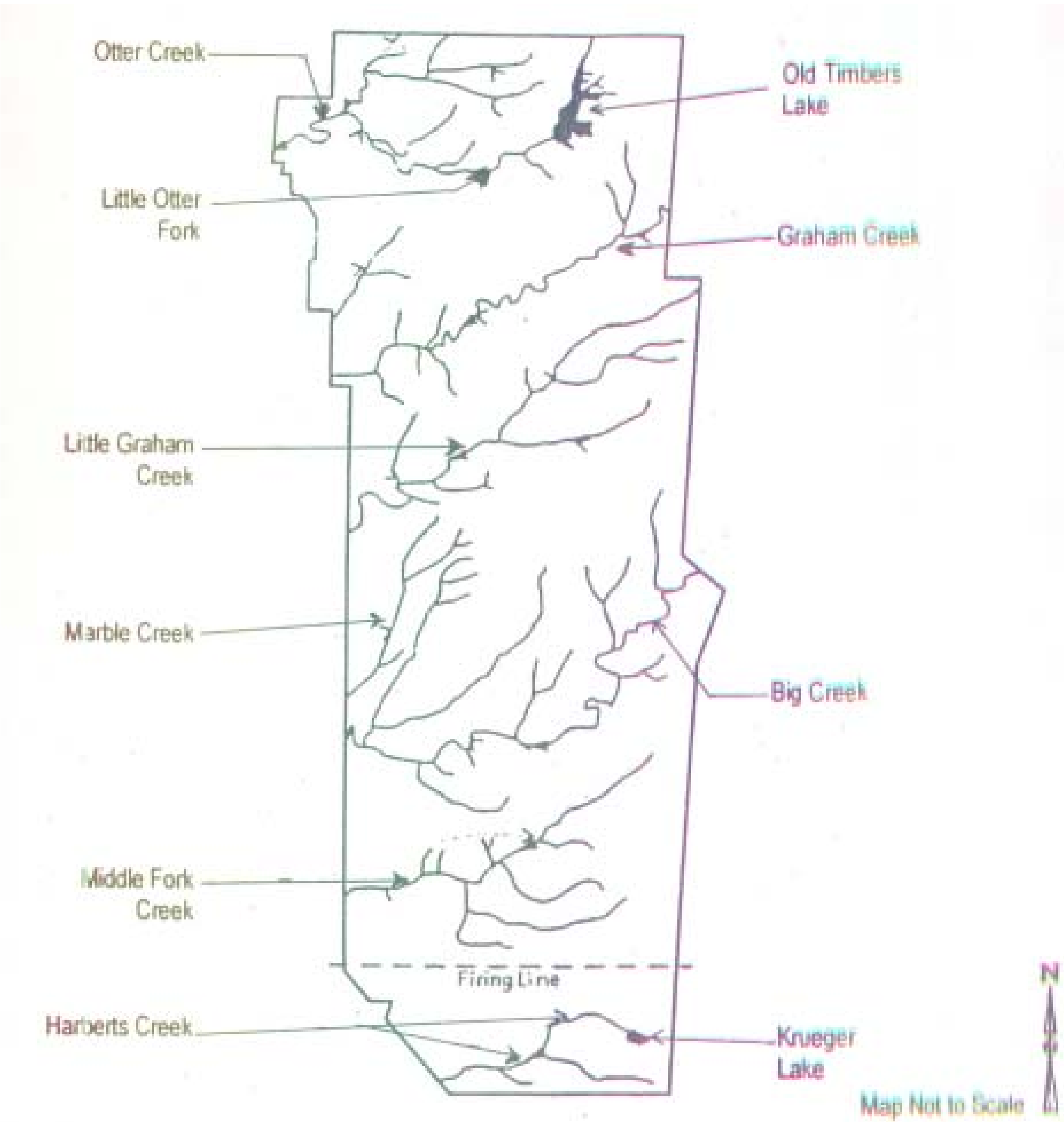
MAP 2, DU Impact Area



MAP 3, Site Building Plan



MAP 4, Surface Water



MAP 5, Site Topographic Plan and Ground Water Monitoring Points

Jefferson Proving Ground: DU Sampling
GROUNDWATER MONITORING WELLS

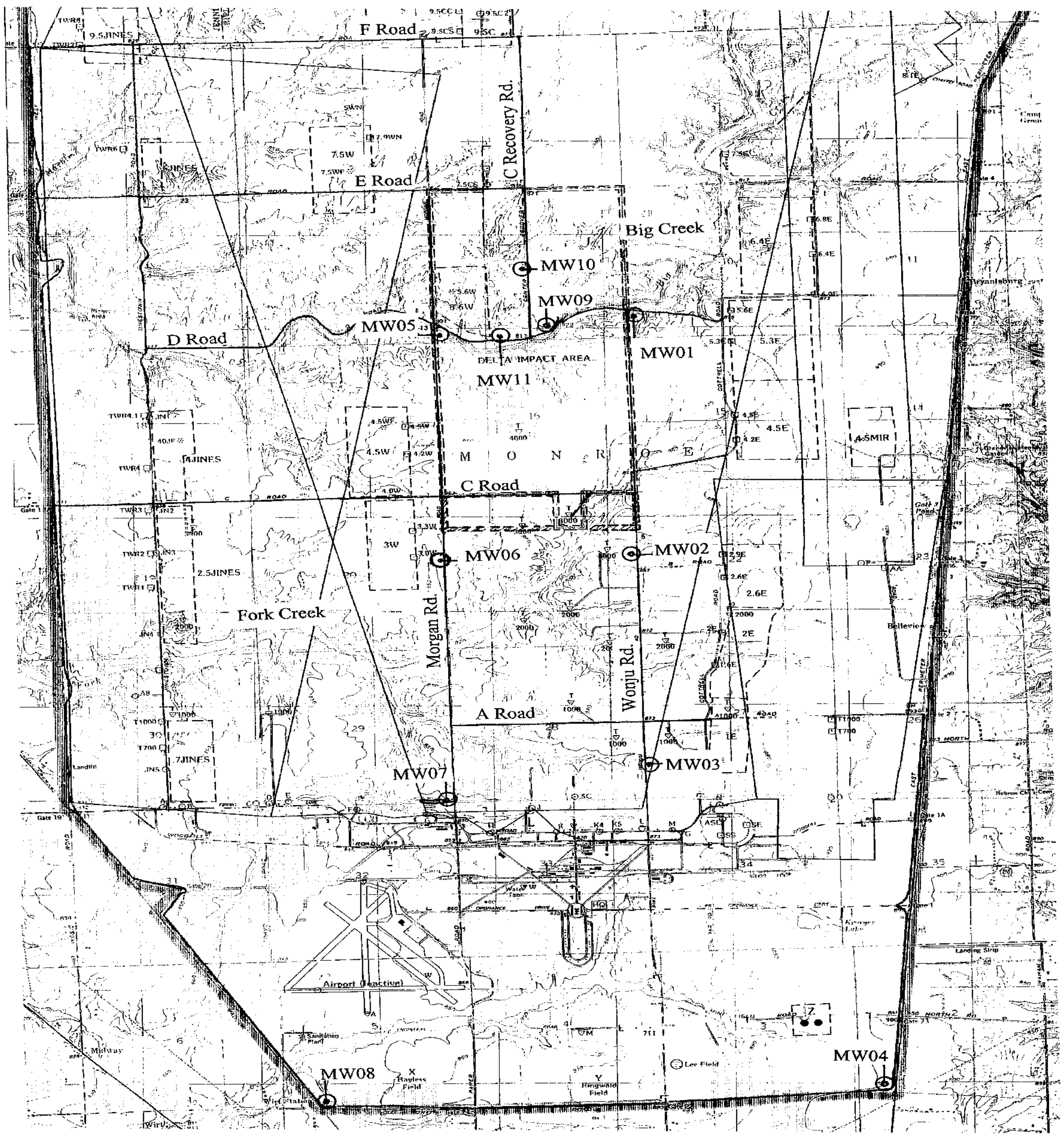
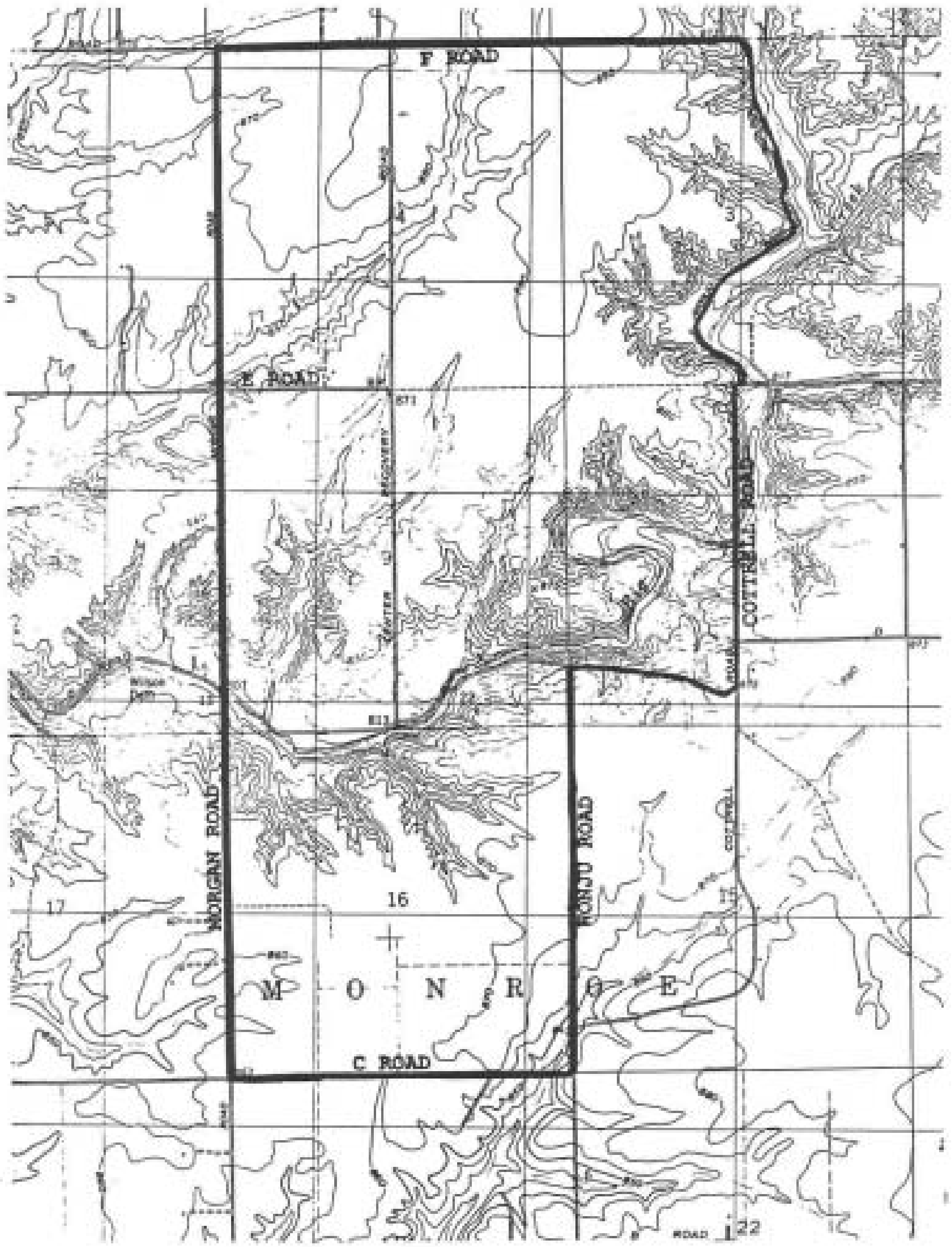


Figure 1: Groundwater samples (Sept. 1997)

MAP 6, DU Impact Area Detail and Topographic Plan



APPENDIX D

ABBREVIATIONS & ACRONYMS

ALARA	as low as is reasonably achievable
BRAC	Base Realignment and Closure
CFR	Code of Federal Regulations
DA	Department of the Army/U.S. Army
DCGL	Derived Concentration Guideline Level
DoD	Department of Defense
DU	Depleted Uranium
EPA	Environmental Protection Agency
ERM	Environmental Radiation Monitoring
°F	degrees Fahrenheit
HPP	Health Physics Program
IAW	in accordance with
JPG	Jefferson Proving Ground
km	kilometer
LANL	Los Alamos National Lab
LTP	License Termination Plan
MOA	Memorandum of Agreement
mrem	milliroentgen-equivalent-man
NMSS	Nuclear Materials Safety and Safeguards
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Guide
pCi/g	picocurie per gram
pCi/ml	picocurie per milliliter
QA	quality assurance
RAB	Restoration Advisory Board
RSO	Radiation Safety Officer
RCCCD	Radiologic, Classic, and Clinical Chemistry Division
SBCCOM	U.S. Army Soldier Biological and Chemical Command
SOP	Standard (or Standing) Operating Procedure
STV	Save The Valley
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
UXO	Unexploded Ordnance

APPENDIX E

NRC LICENSE SUB-1435

NRC FORM 374
(7-94)

U.S. NUCLEAR REGULATORY COMMISSION

PAGE 1 OF 2 PAGES

MATERIALS LICENSE

Pursuant to the Atomic Enemy Act of 1954, as amended, the Energy Reorganization Act of 1974 (Public Law 93-438) and Title 10, Code of Federal Regulations, Chapter I, Parts 30, 31, 32, 33, 34, 35, 36, 39, 40, and 70, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, acquire, possess, and transfer byproduct, source, and special nuclear material designated below; to use such material for the purpose(s) and at the place(s) designated below: to deliver or transfer such material to persons authorized to receive it in accordance with the regulations of the applicable Part(s). This license shall be deemed to contain the conditions specified in Section 183 of the Atomic Enemy Act of 1954, as amended, and is subject to all applicable rules, regulations, and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

Licensee		
1. U.S. Department of the Army 2. U.S. Army Soldier and Biological Chemical Command Aberdeen Proving Ground, MD 21010-5424	3. License Number	SUB-1435 Amendment No. 10
	4. Expiration Date	The license is deemed in effect in accordance with 10 CFR 40.42(c)*
	5. Docket or Reference No.	040-08838

6. Byproduct, Source, and/or Special Nuclear Material	7. Chemical and/or Physical Form	8. Maximum Amount that Licensee May Possess at Any One Time Under This License
Uranium	Depleted uranium metal, alloy, and/or other forms	80,000 kilograms

*The license is deemed in effect in accordance with 10 CFR 40.42(c) until NRC notification of its termination.

9. Authorized use: For possession only for decommissioning. License renewal applications dated August 29, 1994.

CONDITIONS

10. Authorized place of use:

A. The licensed material shall be kept onsite, for the purpose of decommissioning, in the restricted area known as the “Depleted Uranium Impact Area. This area is located north of the firing line, at the Jefferson Proving Ground, in Madison, Indiana 47250.

B. This license has been transferred from the “The U.S. Department of the Army, U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland 21005-5055” to “The U.S. Department of the Army, U.S. Army Soldier and Biological Chemical Command, Aberdeen Proving Ground, Maryland 21010-5424.”

11. A. Licensed materials shall be kept under the supervision of the Radiation Safety Officer, who shall have the following education, training, and experience:

1. Education: A bachelor’s degree in the physical sciences, industrial hygiene, or engineering from an accredited college or university or an equivalent combination of training and relevant experience in radiological protection. Two years of relevant experience are generally considered equivalent to 1 year of academic study.

NRC FORM 374A	U.S. NUCLEAR REGULATORY COMMISSION	Page 2 of 2 PAGES
	MATERIALS LICENSE SUPPLEMENTARY SHEET	License Number SUB-1435
		Docket or Reference Number 040-08838
		Amendment No. 10

2. Health physics experience: At least 1 year of work experience in applied health physics, industrial hygiene, or similar work relevant to radiological hazards associated with site remediation**.** This experience should involve actually working with radiation detection and measurement equipment, not strictly administrative or "desk" work.

3. Specialized knowledge: A thorough knowledge of the proper application and use of all health physics equipment used for depleted uranium and its daughters, the chemical and analytical procedures used for radiological sampling and monitoring, methodologies used to calculate personnel exposure to depleted uranium and its daughters, and a thorough understanding of how the depleted uranium was used at the location and how the hazards are generated and controlled

B. The licensee without prior NRC approval may appoint a RSO provided a) the licensee maintain documentation demonstrating that the requirements of condition 11A are met and b) the NRC is informed of the name of the new RSO by letter to the Regional Administrator, Region II, within 30 days of the appointment.

12. Except as specifically provided otherwise in this license, the licensee shall conduct its program in accordance with the statements, representations, and procedures contained in the documents, including any enclosures, listed below. The NRC's regulations shall govern unless the statements, representations, and procedures in the licensee's application and correspondence are more restrictive than the regulation. .

A. Letter and attachments for license renewal dated August 29, 1994,

B. Letter dated May 25, 1995,

C. Application with attachments dated September 29, 1995, and

D. JPG Security Plan included with the letter dated February 15, 2000.

13. Deleted.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Date: 6/8/2000 By:

Robert A. Nelson, Acting Chief
Decommissioning Branch
Division of Waste Management
Office of Nuclear Material Safety and
Safeguards

APPENDIX F
RISK ANALYSIS

Report Summary: Evaluation of Jefferson Proving Ground for Restricted Release: Risk Assessment Supporting NRC License Termination

M. H. Ebinger
2/7/2001

Jefferson Proving Ground (JPG) was used by the U. S. Army as one of several locations for testing depleted uranium (DU) munitions. Lot acceptance testing of DU weapons began about 1984 and continued through 1994; JPG was closed under the Base Realignment and Closure Act in 1995. In addition to DU fragments, unexploded ordnance (UXO) also remain within the DU impact area and throughout the facility. The U. S. Army is currently seeking termination of its radioactive materials license granted by the Nuclear Regulatory Commission (NRC).

The NRC regulations state the lands can be released for *unrestricted* use if the Army can demonstrate that the total effective dose equivalent (TEDE) to the average member of a critical group is less than 25 mrem y^{-1} and residual radioactivity has been reduced as low as reasonably achievable (ALARA). Reduction of residual radioactivity to reasonable levels depends on costs of such activities and the consideration of additional detriments to workers who provide decontamination and disposal services. Because of the high costs of DU removal and the presence of UXO throughout the site, the expected risks to workers are greater than benefits from reducing radioactivity from current levels. In addition, previous risk assessments cannot support a TEDE of less than 25 mrem y^{-1} to members of some critical groups without institutional controls in place.

Therefore, JPG lands cannot be released for unrestricted use. Instead, the Army will pursue release of JPG lands for *restricted* use under Section 1403 of 10 CFR 20. Criteria for restricted release include: 1) that the TEDE cannot exceed 25 mrem y^{-1} to the average member of the critical group and be kept ALARA while enforceable institutional controls are in place that restrict access to the site; and 2) that the TEDE to the average member of the critical group not exceed 100 mrem y^{-1} if institutional controls fail, less than 500 mrem y^{-1} if contamination reduction is unachievable.

The key to restricted release of the JPG lands is demonstrating that expected exposures to average members of critical groups are less than the regulatory limits. In order to evaluate the potential exposures to DU from the impact area, critical groups were defined by two exposure scenarios. The first scenario is the Occasional Site User, the second is the Resident Farmer. The Occasional User is a site worker who occasionally is required to be on-site in the DU impact area or who is a visitor to the site for short periods limited to about four weeks per year. The Occasional Site User scenario is the most probable because institutional controls will allow for controlled access to the DU impact area. The Resident Farmer scenario was used to evaluate the exposure from full time farming by a subsistence farmer on the DU impact site. The farmer is assumed to grow and consume all necessary vegetable, diary, and meat products on the farm, and drinking water is obtained from shallow, on-site wells. The Resident Farmer scenario is improbable for two reasons. First, institutional control will be enforceable since access to the lands will be controlled by the federal government, although not by the Army. Farming on the DU impact area would not be permitted as long as institutional control is maintained. Second, use of the DU impact area for farming would be dangerous because of the presence of UXO, the difficulty of removing current UXO, and the impossibility of assuring that all UXO had been removed.

The estimated doses to the average member of the two critical groups show that TEDE limits can be met for potential exposure to DU. Predicted maximum doses to the average member of the Occasional User critical group are about 3.9 mrem $y^{-1}$and range from 1.6 to 3.9 mrem y^{-1}. The predicted maximum TEDE to the average member of the Resident Farmer critical group are about 63 mrem y^{-1} and range from about 27 mrem y^{-1} to 63 mrem y^{-1}. The range represents the dose estimates using average soil and water concentrations (smaller value), whereas the maximum doses (larger value) use the largest reasonable concentrations of DU in soils and water. All concentrations used in the dose estimates were derived from measurements of soils and water from the JPG DU impact area.

The results of the exposure and dose assessments support release of JPG lands for restricted use as defined by the NRC. It should be noted that these dose results pertain only to TEDE from DU, not to additional risk of death or injury from exposure to UXO.

Evaluation of Jefferson Proving Ground for Restricted Release: Risk Assessment Supporting NRC License Termination

Prepared by
Michael H. Ebinger
Environmental Science Group (EES-15)
Los Alamos National Laboratory

For
U. S. Army
Soldier, Biological, and Chemical Command
Aberdeen Proving Ground
Edgewood, MD

Revised 15 June 2001

Los Alamos National Laboratory Report LA-UR-01-825

A. INTRODUCTION

Jefferson Proving Ground, Indiana (JPG), was used by the U. S. Army as one of several locations for testing various munitions used in combat. One of the main activities at JPG was the lot-acceptance testing of depleted uranium (DU) penetrator munitions. Testing of DU munitions began about 1984 and continued through 1995 when JPG was closed under the Base Realignment and Closure Act (BRAC). Also under BRAC was the need to transfer Army lands out of Army ownership and into private ownership, or made available for use to the public as appropriate. The south part of the former JPG was transferred to private ownership; however, significant hazards exist north of the former firing line, and these lands cannot be safely transferred. Instead, much of the JPG site has been converted to a managed wildlife area, Big Oaks National Wildlife Refuge, with controlled access. The DU impact area occupies part of the central section of the new refuge and is contaminated with DU and unexploded ordnance (UXO). Both DU and UXO are considered dangerous and access to the area must be controlled in order to assure the safety of site users.

The U. S. Army is seeking a termination of its radioactive materials license (license number SUB-1435, Amendment 10) and release of the lands for restricted use as defined in 10 CFR 20, Section 1403. This report is the risk analysis that supports release for restricted use, and the assessment approach and results are presented below.

Problem Definition

There are two criteria for release for restricted use that the current risk assessment will address (U. S. NRC, 2000). First, as long as institutional controls are in place, the total effective dose equivalent (TEDE) to the average member of a critical group cannot exceed 25 mrem y^{-1} and must be kept as low as reasonably achievable (ALARA). This criterion pertains to exposures and doses to humans when institutional controls are in place at the site. The second criterion is operative if institutional controls at the site fail. In this case, the TEDE to the average member of the critical group must be less than 100 mrem y^{-1}, less than 500 mrem y^{-1} if reduction of contamination is technically unachievable, or ALARA. Scenarios to test both conditions will be developed below, and release of JPG for restricted use will be evaluated. The objectives of this investigation are: (1) to evaluate the possible doses to humans through different exposure scenarios and the consequent dose to humans in the critical group or population that is exposed; (2) discuss the parameter values used in the evaluation since not all values are known with the same degree of accuracy; (3) present the modeling approach used in the risk estimates; and (4) evaluate the expected doses to a member of the critical group against the dose limits established in 10 CFR 20 section 1403.

The main difficulties in estimating the dose to members of the critical group are: 1) the uncertainty in the amount of DU in the soils at the DU impact area; 2) the distribution of DU throughout the impact area; and 3) the need to use default values for many of the environmental parameters required to run a dose assessment model. These difficulties will be addressed throughout this report, and the effects of the approximations on the predicted doses will be discussed.

B. Existing Data and Analyses from JPG

Environmental Monitoring Data

An environmental monitoring plan was developed for the JPG DU impact area before the initial DU munitions were fired in 1984 (Abbott, 1983), and the monitoring plan is still in use. Sampling locations for soils, surface water, and groundwater are shown in the environmental monitoring plan, and the sampling design for vegetation and biota are also presented. Twice each year, samples were collected and analyzed for total U and, often, the isotopic composition of U in samples. The environmental sampling data are reported elsewhere (Abbott, 1983) and summarized for the 1984 –1994 period (Ebinger and Hansen, 1996a). Soil concentration data for the DU impact area from 1984- 2000 (Table 1) show that the distribution of concentrations is skewed, with mean value of 18.8 pCi g^{-1}, and a median value of 1.5 pCi g^{-1}; the standard deviation of these samples is almost 200 pCi g^{-1} (Figure 1). Of the 388 samples analyzed since 1984, only 90 are greater than 2 pCi g^{-1}, the overall average background soil concentration of U at JPG. Similar distributions for DU concentrations in groundwater and surface water were obtained for the same period (Table 1; Figures 2 and 3). The summary of the environmental data indicates that the expected concentrations of U or DU are significantly less than the derived concentration guideline of 35 pCi g^{-1} for soil and 150 pCi L^{-1} for surface water and groundwater (U. S. Army, 1996). The summary data suggest that there was relatively low risk to site users throughout the testing period at JPG; the effects expected over the next 1000 years will be estimated using these and other site specific data in the remainder of this report.

The hydrology of JPG lands south of the firing line was evaluated during remediation efforts associated with BRAC and the land transfer from the Army (Rust, 1994; 1998). The groundwater hydrology at JPG is complicated because of the karst terrain, but the overall flow was thought to be parallel to the flow of the streams that cross the DU area, namely Big Creek. Establishing the regional hydrology was not within the scope of the Rust reports, nor was the deeper groundwater hydrology at the site.

Therefore, detailed descriptions of the overall hydrologic setting cannot be made at this time.

Several monitoring wells were completed around the DU firing range between 1984 and 1994. These wells were bored to various depths that ranged to over 40 feet from the surface (well logs, personal communication with Richard Herring Jefferson Proving Ground, retired; SBCCOM and U. S. Army CHPPM staff, Aberdeen Proving Ground). The groundwater data indicate some variation in the concentration of U in wells between 1984 and 2000 (Figure 2), the largest of which was attributed to error in sample handling at the analytical laboratories (Ebinger and Hansen, 1996a). Overall, however, the data indicate no long-term contamination moved to the groundwater or surface water from the DU impact area. This conclusion was further supported by the isotopic composition of U in the groundwater samples (Ebinger and Hansen, 1996a, figure 6 therein). Ratios of the activity of ^{234}U to ^{238}U near 1 indicate U from natural sources, not DU from the impact area, whereas isotopic activity ratios near 0.09 indicate DU (Shleien, 1992).

Surface water monitoring locations were along Big Creek upstream and downstream from the DU impact area. There was variation in the concentration of U in the measurements over the 1984-2000 period, but there was neither long-term elevation of the concentration, nor sustained, elevated concentration at any sampling site. The slight increases in U concentration measured in the surface water could be due to U incidentally applied as a trace constituent of phosphate fertilizer used throughout the farming community that surrounds JPG (Klement, 1980; Eisenbud, 1987). Isotopic ratios in the environmental monitoring data set further support that most of the variation in concentration was due to a natural source of U in surface water and not DU. The summary data suggest that the main source of U in surface waters has been natural in origin, that is, from fertilizers or derived from geologic deposits and transported via water or erosion. Whether from natural sources or agricultural fertilizer, the concentrations are well below the Army derived concentration guidance levels (DGCLs; U. S. Army, 1996) and low enough to be of little concern.

Previous Risk Assessments

Several risk assessments for the potential effects of DU on members of a critical group have been conducted at JPG (Ebinger and Hansen, 1994; 1996a, 1996b; 1998). The predicted doses to receptors depended largely on the assumptions made about exposure pathways. In the earliest assessments, it was demonstrated that drinking water was the largest contributor to the overall dose to humans. In addition, the largest doses were predicted when DU, assumed to be readily soluble in water, was released to surface water and was present at the beginning of the assessment. These assumptions were to illustrate the worst-case scenarios, that is, the case when a large fraction of the DU inventory was readily available via many of the pathways modeled. Since the first assessments, however, refinements were made about DU transporting to the groundwater and surface water supplies, and the need to be more realistic than the worst-case scenario was also made clear. The most recent assessment assumed that the soil and geologic media that control groundwater recharge and DU transport were characterized well enough to use as modeling scenarios. This assumption is optimistic given that the hydrologic data (Rust 1994, 1998) were obtained from an area about 5 miles southwest of the DU impact area and may not be completely relevant to the hydrology of the DU impact area. The approach adopted for this report is to model the transport of DU at JPG with as few estimates as possible, relying more on default parameters defined by the modeling code or by current guidance on decommissioning and risk assessment. These default values are also estimates with large uncertainties, but they have been accepted by the regulatory community as alternatives when better, site-specific values are not available.

Initially, there was no information on the distribution of DU in soils of the DU impact area, so the total expected inventory was assumed to be in the top 15 cm of the soils, and an average value was calculated in that manner. Two reports show that the size of the affected area could be more reliably estimated after radiological surveys along a grid through the DU impact area were completed (SEG, 1995, 1996). These survey data were used to map exposure rates at the surface of the soil. These maps were useful for area delineation, but were difficult to use for source term estimation because they measured radiation rate from all radionuclides present at the surface of the soil. The radiation rates were converted to concentrations of DU in soil under the assumptions, probably inaccurate at best, that: (1) all radionuclides in the soil were DU; (2) that there was little to no shielding of the signal due to soil particles, water in the soils, or vegetation in and on the soil; and (3) that the recorded signal was directly proportional to the concentration of DU in the soil. The source terms in the most recent report (Ebinger and Hansen, 1998) are the result of a refined estimate of the affected area from the SEG (1995, 1996) data and use of maximum and average concentration estimates from survey data and previous assessments.

C. Scenario Definition and Exposure Pathway Identification

Two scenarios were evaluated in this dose assessment and represent the range of potential exposures of humans to DU at JPG (Table 2). Each scenario has a distinct set of exposure pathways that will be identified below. The NRC Industrial Occupant scenario (Occasional User Scenario in the current report) and Resident Farmer scenario were the basis for building the two scenarios tested in this report (Kennedy and Strenge, 1993; U. S. NRC, 2000). These scenarios were modified and exposure pathways were developed using site-specific information where that information was relevant and applicable, or from default values defined elsewhere (Kennedy and Strenge, 1993; Yu et al, 1993b; Beyeley et al, 1996; U. S. NRC, 1998a).

A third scenario was also tested and involves potential inhalation of airborne DU particles as a result of fires on JPG lands. The RESRAD model includes inhalation pathways for livestock and humans, but the concentration of DU in the air depends on the concentration of DU in soils of the contaminated area. Therefore, a separate estimation was made assuming that a 70 kg person inhaled air at a rate of 8,400 m^3 y^{-1} (Yu et al., 1993b) and was exposed to smoke that contained 2.5 x 10-5 pCi-DU m^{-3} all year (Williams et al, 1998). This would be the largest dose possible based on available data on DU in smoke plumes from fires (Williams et al., 1998).

Due to the risk of injury or death from the many UXO rounds on the site, it is not realistically possible that JPG lands could return to farmlands in the future. However, for the purposes of this investigation, it will be assumed that the land could be cleared of UXO and the forest converted to farmland. In this scenario, subsistence farms could provide meat and vegetables for a resident farmer. Potential DU transport pathways include: (1) drinking water that is contaminated with DU; (2) irrigation of vegetables and watering of livestock with contaminated water; (3) growing forage and vegetable crops in contaminated soil; (4) consumption of contaminated crops and/or feeding contaminated forage to livestock; (5) inhalation of dust that contains DU or contaminated soil; (6) external exposure due to DU in the upper soil layers; and 7) ingestion of soil by humans and animals (Figure 4). This conceptual model will be the basis for adapting a mathematical model that will be used to test the effects of assumed exposure to DU at JPG.

Occasional Site User

The occasional user for the purpose of this assessment is either a person using the site for recreational hunting or a site worker who visits the site periodically throughout the year. Both scenarios are plausible under current and anticipated site use plans. Currently, hunting is allowed at specific JPG locations during certain times of the year. During these times, hunters are allowed access to explicit locations within JPG and are allowed to remove game animals (e.g., deer, turkey) from the site according to game license restrictions. Hunting is not allowed on or near the DU impact area, but for the purposes of this assessment, hunting on the DU area will be assumed. Site workers are potentially exposed to DU when they are allowed in the DU impact area for various reasons relating to facility operations, such as sampling for environmental monitoring or fence maintenance.

The on-site time allotted to the occasional user, whether a hunter or a site worker, is 4 weeks per year. This exposure time was based on the most frequent use of the area by local hunters over the course of several hunting seasons, and the time it takes to sample the DU impact area for environmental monitoring.

The occasional use scenario differs from the Industrial Occupant scenario (U. S. NRC, 1998a) in that the users are not inside a building, thus the users have no contact with contaminated building surfaces. Exposure pathways that are included in the occasional user scenario and are similar to the Industrial Occupant are: (1) external exposure to DU; (2) inhalation of airborne radioactive material; and (3) inadvertent ingestion of DU. The occasional user is assumed to bring all food and drinking water needed during the site visit from an off-site, uncontaminated source. An additional pathway unique to the occasional user scenario at JPG is off-site ingestion of game animals taken from the DU area. Data on tissue concentrations in game animals from JPG are not available, but data from Aberdeen Test Center and subsequent calculations of dose to humans from consumption of potentially contaminated deer meat indicate that there was no adverse risk to the consumers of the deer meat (Ebinger et al., 1996). For example, deer would be exposed to DU through forage uptake of DU, wind deposition of DU on forage materials, ingestion of soil during feeding, and ingestion of DU from drinking water. Extrapolation of APG data to JPG exposure scenarios is justified only for comparative purposes. This extrapolation assumes that exposure conditions for all receptors are identical between APG and JPG, assumptions that were neither verified with field data nor considered reasonable. Thus, there is high probability that field data on U or DU in deer tissue may be different than the same data from APG.

Resident Farmer

The resident farmer scenario is based on assumptions discussed for decommissioning (Kennedy and Strenge, 1993; U. S. NRC, 1998a) and mainly allows that a farmer grows crops, raises livestock, consumes meat and vegetables produced on-sight, and drinks water from a well that is potentially contaminated. In order for this scenario to occur at JPG, institutional controls will have failed and the resident farmer is assumed to have free access to the DU area as well as the remaining land at JPG. This scenario is important for two additional reasons. First, failure of institutional controls implies that the knowledge about the inherent dangers of using the JPG lands has vanished with the institutional controls. It is assumed that the resident farmer at JPG knows nothing of the potential hazards of using the former test areas. Second, any farming activity such as plowing or tending crops necessarily exposes the farmer and workers to significant non-radiological risk of injury or death from accidental detonation of unexploded ordnance throughout the JPG site. The consequences of such accidents is clear, and predicting the potential frequency of such accidents or estimating their severity is beyond the scope of this report and outside the concerns of the NRC license.

The resident farmer will consume drinking water from wells constructed in local aquifers. While this part of the scenario is acceptable, it is most likely improbable. Currently, many of the water users near JPG use water form the City of Madison for drinking water. Also, anecdotal evidence from well sampling indicates that the water derived from the upper 50 feet of the local aquifers, at least within the JPG DU area, is not potable without extensive treatment due to sulfides and coloration. For the purpose of providing a conservative assessment, though, drinking water from local wells will be included in the resident farmer scenario.

Exposure pathways for the resident farmer scenario are as indicated by Kennedy and Strenge (1993) and NRC (U. S. NRC, 1998a, b) with some modifications to accommodate the RESRAD coding. Ingestion of farm products such as meat, milk, and vegetables integrates the exposure of livestock and vegetable crops from soil and water sources and passes the associated DU concentration through the food chain to the resident farmer. Thus, fodder is also grown on site and fed to livestock, vegetables are irrigated with water that is presumed contaminated with DU, and milk is produced by cows that consumed contaminated fodder and water. Contributions to the total dose received by the resident farmer via these pathways are included and calculated in the RESRAD program and will be discussed more fully below.

D. System Conceptualization

Site Characteristics

The area enclosed by JPG is considered ideal farming land because of the favorable temperature during the growing season, relatively long growing season, and adequate moisture to grow all crops of the temperate Midwest without added irrigation and without danger, most years, of drought (USDA, 1997). Adequate surface and groundwater sources exist to ensure a useful water supply, and the Ohio River flows within 10 miles of the south boundary of JPG and could be used as a water source as well. The

JPG area now is forested with various hardwoods, herbaceous cover, and grasses, and supports a large population of game animals, non-game mammals, aquatic life, and reptiles. Between the late 1800s and 1943, JPG lands were cleared and farmed extensively, but returned to a forest ecosystem after the U. S. Government took control of the area in World War II. The landscape is cut from east to west by several rivers, notably Big Creek that flows through the DU impact area. Trenches running north to south where trees have been removed due to firing of DU munitions mark the forest landscape. The trenches or firing lines are enclosed within the DU impact area.

Soils of the area are mainly derived from glacial till covered by up to one meter of loess (Nickell, 1985). The combination of loess and till, along with the annual precipitation of nearly 40 inches (1 m), can cause fragipan formation in the soils of the area, that is, a soil horizon of seasonally low permeability. Fragipans inhibit movement of water into or through the soil, thus the soils are ponded during some parts of the year. Soils are at least a meter deep on average, and unsaturated subsoils extend to a maximum of 6-7 meters in depth in some cases. Shallow bedrock formations include limestone with interbeds of pyritic shale, and these are commonly observed in stream sediments, bank cuts, and road cuts in and around JPG. Water movement into and through the soil and deeper geologic media is assumed to be parallel to the flow of the main streams (e.g., Big Creek). Detailed hydrologic studies have not been conducted, but previous work showed that subsurface water flow is in the direction of the streams (Rust, 1994, 1998).

Conceptual Model

Currently there is known DU contamination in the soils of the impact area. Several studies document the concentrations of DU in the soils (e.g., Ebinger and Hansen, 1996a) and two show the potential distribution of DU within the area (SEG, 1995, 1996). The conceptual and mathematical models assume DU will be transported from soil through the environment via several pathways to ecological receptors or humans. Doses to humans are the focus of this report, but doses to ecosystem receptors are implicitly included in this analysis because they supply part of the dose to humans. In concept, DU moves by a variety of processes after it is deposited in the soil. DU can dissolve within the soil and leach to groundwater; the dissolved DU can react with soil minerals that slow its transport to groundwater; and soluble DU can be taken up by plant roots and incorporated into various plants. Soils are also susceptible to wind and water erosion, thus DU could be transported through the air or moved into surface waters by various erosion processes. In addition, since plants grow in the soils that are contaminated, ingestion of plants by animals necessarily includes incidental ingestion of DU-contaminated soil. DU. Last, DU may transport through groundwater from wells to drinking water supplies, or be used as well-derived irrigation water, in which case the DU is recycled to the soil and is transported again. Doses to humans and ecosystem receptors can be realized along exposure pathways from the time of deposition to the time of removal from the system. Thus, the dose from DU must be assessed for a variety of pathways, and must also be assessed over a relatively long time due to slow transport through soils.

Mathematical Model

Various mathematical models could be used to estimate the doses from DU exposure in soils through the many environmental pathways. The DOE program, RESRAD1 (Yu et al, 1993b), was chosen for this assessment for a number of reasons. First, the program is flexible enough to accommodate site-specific information for many of the parameters required of an assessment. Second, the Department of Energy developed the program specifically to evaluate the risk of residual radioactive material in soils under different site-use scenarios. Third, several risk assessments have been completed for JPG, and RESRAD was used for this work (Ebinger and Hansen, 1994; 1996a, b; 1998). Fourth, RESRAD version 6.0 has been developed to include the accepted values of many default parameters (i.e., not site-specific values but values required to run the program) discussed by Kennedy and Strenge (1993), Beyeley et al (1996), and NRC (1998a). Use of RESRAD was intended to accommodate a widely accepted assessment code within the decommissioning and license termination venue.

The RESRAD program simulates the transport of DU (or other radionuclides) through soils to various crops and plants of use to a farmer, to groundwater used for drinking, and finally to the farmer or user of the site under investigation (Figure 4). The program uses a relatively simple leaching model to move DU through soils to groundwater, and requires an input concentration of radionuclides in the soil of the affected area. The soil concentration, or source term, is assumed to be uniformly distributed over the affected area, and is diminished only by radioactive decay, leaching, wind and water erosion, and uptake from soils, water and air. The leaching model depends on several soil properties, including permeability, texture, and the distribution coefficient between soluble (i.e., mobile) DU and insoluble DU that remains in the soil and is not leached. Groundwater flow also depends on the permeability of the geologic strata through which it flows as well as the structure of the underlying bedrock. The depth through which the DU migrates

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1 RESRAD Version 6.0 was modified by the code’s authors to include the NUREG 5512 default values. RESRAD Versin 6.0 was obtained from the DOE Center for Risk Excellence, Argonne National Laboratory, for this analysis.

depends, again, on the underlying geologic formations and the depth of the water table. In general, DU and other contaminants simulated with RESRAD move more quickly in saturated, porous materials that are relatively thin in depth, whereas transport is slowed when the materials are less porous, deeper, react with the contaminant, or a combination of these. Thus, the relatively simple idea of leaching a uniform concentration of a radionuclide through soils and underlying rock is quickly complicated by various natural processes that control contaminant flow through soils and rocks.

The RESRAD program requires values for several dozen parameters in order to simulate contaminant flow from the source (i.e., contaminated soil) through the unsaturated and saturated media to groundwater or surface water. A general set of default parameters is built into RESRAD (Yu et al, 1993b; U. S. NRC; 1998a) and is based on "average" agricultural characteristics reported in the technical literature, or recently, on default values important to the decommissioning community (U. S. NRC, 1998a). Default values more specific to license termination and/or decommissioning, hereafter called the NUREG 5512 default values, have been integrated into NRC guidance (Kennedy and Strenge, 1993; Beyeley et al, 1996; U. S. NRC, 1998a). A comparison of the RESRAD and an NRC program, DandD, is made in NRC (U. S. NRC, 1998a), and the two sets of general default values are also compared. Also, RESRAD version 6.0, used in this analysis, has been modified by the code's authors to include the NUREG 5512 default values for simulations. A catalog of default values used for the JPG analysis is given in Appendix A.

RESRAD Inputs, defaults, and uncertainties

The RESRAD program, the conceptual model of JPG, and the difficulties in estimating the soil concentration of DU at JPG illustrate the most problematic parts of any risk assessment, that of assigning values to modeling parameters. RESRAD values for several dozen parameters, many of which can be either default values or site-specific values that would represent a more realistic case than general default values. However, site-specific parameters for all modeling needs would be a prohibitively expensive and time consuming effort, and often values for many non-critical parameters are estimates from the literature or default values determined by the program custodians and developers.

RESRAD Inputs. While many values required to run RESRAD are included in the program, the source term, or concentration of contaminant in the soil, is not and must be supplied by the user. The estimation of the concentration of DU in the soils at JPG was particularly problematic. Deposition of DU in the impact area is anything but uniform as shown earlier in the review of the environmental monitoring plan data from 1984 through 2000 and in the radiological surveys (SEG, 1995, 1996). For example, if the average concentration of DU in soil is estimated from the mean of the entire pool of the environmental monitoring samples, the value is 18.8 pCi/g with a standard deviation of nearly 200 pCi/g. Alternatively, if the median value of 1.4 pCi/g is used as the soil concentration, the “contaminated” soil is indistinguishable from the background concentration of U.

Several source terms were used in the past risk assessments, all based on a different set of assumptions. The values of the source term and the size of the affected area reflect refinements in measurements and the overall understanding of the DU distribution. In order to estimate the upper and lower bounds of the potential doses to humans, a range of soil concentrations has been developed that reflects the uncertainty in the soil concentration data (Table 3). These values represent the estimates of DU concentrations in soils based on environmental monitoring data (Abbott et al., 1983; Ebinger and Hansen, 1996a) and the radiological surveys completed within the impact area (SEG, 1995, 1996). The derived concentration guideline level (DCGL, also referred to as release criteria values) of 35 pCi g^{-1} was used in this risk assessment to reflect the impact of derived concentration limits on the risk assessment (U. S. Army, 1996), and 90 pCi g^{-1} represented a large but realistic soil concentration. Potential doses to humans were estimated using these source terms in separate modeling calculations.

A second parameter that is critical to the dose estimations is the size of the affected or contaminated area. In the initial risk assessments, the contaminated area was assumed to be the entire DU firing range for lack of a better estimate. This value was reduced somewhat after refinements to the distribution of DU in the contaminated area (SEG, 1995; Ebinger and Hansen 1996a), and reduced further after more critical analysis of radiological survey data (SEG, 1996; Ebinger and Hansen, 1998). The present size of the contaminated area is estimated at 5×10^5 m^2 and includes the firing lines and DU dispersion areas north of Big Creek. The immediate affect of the smaller area on the humans using the area under either scenario is to concentrate the contamination and leach it into the aquifer more rapidly than might be expected from a more disperse source term. However, the smaller affected area also triggers larger predicted doses to humans, thus the potential to over-estimate the actual dose is built in to the prediction; in other words, the predictions are designed to add a margin of safety by erring toward larger predicted doses, not smaller.

In addition to the area of contamination, the depth to which the soil is contaminated is also of concern. Default depths are currently 15 cm (Yu et al, 1993b; NRC 1998a), and previous DU concentration with depth supports the 15 cm contaminated zone (Ebinger et al, 1996). Thus, the contaminated zone is the 5×10^5 m^2 of the impact area with the 15 cm depth within which much of the DU contamination is found.

The structure of the unsaturated and saturated media through which leached DU will be transported greatly influences the concentration that is available for uptake by animals and humans as well as the amount of time needed to transport the DU through the media. Deeper, reactive soils and substrata will sequester DU for longer periods of time and delay discharge of the DU to groundwater and surface water when compared to thinner, unreactive soils and rocks. Soils survey information (Nickell, 1985), well-log data, and recent hydrologic reports (Rust, 1984, 1998) suggest that significant retardation should occur beneath the contaminated zone. However, specific measurements of parameters such as permeability, the distribution coefficient, and the solubility of DU in water within the soils and rock have not been made. Risk estimates without these parameters could be made, but doing so adds uncertainty of unknown magnitude to the predictions. The option to model a simpler system of 1 m of soil over a relatively permeable aquifer was provided as a default in both NRC (Kennedy and Strenge, 1993; U. S. NRC, 1998a) and DOE (Yu et al., 1993b) approaches. While this approach is not as realistic as it could be, it is the conservative approach and will be used for the dose assessments. A more realistic approach would include the actual soil depths, properties, and measured values for distribution coefficients.

Distribution coefficients depend on many properties such as soil pH, redox state, mineralogy, texture, and others. In general, measuring distribution coefficients is costly and time consuming; for the purposes of this risk assessment, default values for distribution coefficients were used. Choice of the default values was based on critical review of K_ds in the literature (Sheppard and Thibault, 1990; Kennedy and Strenge, 1993; Yu et al., 1993). The distribution coefficient used was the most conservative default value, namely either 15 (NRC 1998a) or 50 (Yu et al, 1993a; 1993b), and either represents conservative values.

Additional Default Values for JPG Simulations. Numerous additional default values were used in order to make the dose predictions for JPG. The RESRAD defaults were changed, when possible, to correspond to the values suggested as NUREG 5512 defaults and contained in the DandD program. The results of the different simulations are shown below. Appendix A is a catalog of the defaults used for this assessment, and deviations from NUREG 5512 values are noted; Appendix B contains input files for the resident farmer scenario and the occasional use scenario.

Uncertainties in Modeling Parameters. The largest uncertainty in the predictions for JPG are in the source term for the contamination. As mentioned above, the distribution for the predictions is assumed to be uniform throughout the affected area. The environmental summary data clearly show that the source term is not uniformly distributed. The combined affected area of 5 x 10^5 m^2 and the derived average concentrations of 35 pCi g^{-1} and 90 pCi g^{-1}, however, should bound the upper limits of the predictions.

The distribution coefficients (K_ds) for U or DU vary significantly in the literature (e.g., Sheppard and Thibault, 1990; Yu et al. 1993a, 1993b), and this variation could affect doses, time at which contamination enters groundwater, or both. For that reason, the simulations were made using the two set of values. Thus, 8 predictions were completed and are presented below. The wide variation of measured K_ds reported in the literature illustrates the difficulty in obtaining actual values. Since K_ds depend on many soil or rock properties and are assumed to be an equilibrium value, temporal change in one or all of the properties affects the K_ds. It is for this reason that conservative default values were used to bound the upper limit of dose.

Soil and groundwater flow parameters such as porosity, hydraulic conductivity, flow rate, and stratum thickness are largely unknown for the JPG area. Some data indicate deeper groundwater than the 1 m depth used in the predictions reported here (Rust, 1994, 1998; well-log data), but these data cannot be extrapolated to the entire DU impact area without increasing uncertainty in the predictions. Thus, it was decided to use the more conservative values in the modeling, that is, those values that would tend to result in the largest risk from exposure to DU. The default parameters were the chosen values. However, there is still significant uncertainty in the predictions made with the default values, probably toward over-estimates of the actual risk to receptors. First, the predictions using the default parameters do not account for actual retardation of DU by deeper soils and subsoils. Smaller K_ds could decrease the predicted dose significantly, but depends on obtaining measured values. Second, the predicted values do not account for actual use of groundwater obtained from off-site wells by many residents in the area. Since drinking water was shown to be the pathway that accounted for the largest percentage of the dose to humans, use of an uncontaminated source of drinking water would reduce the expected dose to humans in any scenario. The results reported below reflect the use of the default parameters; if uncertainty in the values were decreased by incorporating measured values, the overall risk would decrease and the assessment would be a more realistic reflection of the actual risk at the site. On the other hand, if the predicted doses are less than the guideline values as defined above, the simplistic approach would have the power to demonstrate the compliance of a more realistic system. Without enormous costs for sampling and characterization of the soils and groundwater, though, the default parameters are the most conservative while still realistic values for this risk assessment.

E. DOSE ASSESSMENT RESULTS

The results of the RESRAD simulations indicate that the resident farmer is potentially exposed to larger doses than the occasional user as expected, and that the peak doses come at very different times depending on the scenario (Table 4). Predicted doses to the resident farmer are mainly from contaminated drinking water (Figure 5), whereas the major portion of the dose to the occasional worker or hunter is from external radiation and from soil adhesion to plant surfaces (Figure 6).

The effect of the choice of K_d is also clear in the resident farmer scenario. Reduction of the K_d by a factor of 5 increases the dose to the farmer by about a factor of about 4 (Table 4). The time to peak dose was also 50 years sooner with the smaller K_d, and both findings are in line with expectations. Smaller K_ds mean that more of the contaminant is in the soluble, mobile form and moves through the soil and rock strata faster than if larger K_ds are chosen. Larger K_ds, on the other hand, result in more of the contaminant being sequestered in the soil and rock strata for longer times and released to groundwater more slowly. Thus, the time to peak dose is greater than with smaller K_ds, and the total dose is significantly smaller. K_ds had little effect on the dose to the occasional user because part of the dose was due to external radiation from the ground surface which is affected only by soil concentration, and part was due to DU transport of contaminated soil to plant surfaces, a pathway that does not involve movement with water through soil.

Another factor that is clearly illustrated in the RESRAD results is the choice of soil concentration for the simulation. The dose is proportional to the soil concentration, no matter which scenario is used. This intuitive result is useful in understanding the uncertainty of the calculations. For example, if the soil concentration in the DU impact area is determined to be less than either of the values used here, the dose would be proportionally lower than the doses predicted in this report. Conversely, dose would be larger if a larger soil concentration were used.

The dose expected from inhalation of DU-containing air was estimated for a 70 kg human breathing the contaminated air for an entire year. While this pathway is unreasonable because of the amount of time spent in the smoke plume of a forest fire, it does serve to illustrate the largest expected dose to the recipient. Assuming that the maximum concentration of DU in smoke resulting from a forest fire is 2.5 x 10-5 pCi m^{-3} (Williams et al., 1998), the dose to the receptor is about 2.5 mrem y^{-1}, and less time spent in the smoke plume would obviously reduce the dose received. Even with no reduction in expected dose factored in, the contribution of the dose from inhaled smoke does not significantly increase the dose to either the Occasional User or the Resident Farmer.

F. Restricted Release Evaluation

The NRC stipulation for restricted release are: 1) that the dose to a member of the critical group be less than 25 mrem y^{-1} or ALARA if institutional controls are in place, or 2) that the dose to a member of the critical group be less than 100 mrem y^{-1} if institutional controls fail, or less than 500 mrem y^{-1} if controls fail and it is technically impossible to reduce the activity further. Institutional controls are assumed in place for the testing of the occasional user scenario. No access by hunters and little access by site workers is planned at JPG as part of the institutional controls that are in place and will be continued into the future. Institutional controls are assumed to have failed when considering the resident farming scenario, and unlimited access was permitted. This latter scenario is improbably given the large number of UXO on the JPG site and the need to pass the knowledge of those dangers to any potential land users in the future.

The predicted risk from the occasional use scenario ranged from 1.6 mrem y^{-1} to 3.9 mrem y^{-1}, and is well below the 25 mrem y^{-1} limit set by the NRC for restricted release. Even with large uncertainties in the data and, thus, uncertainty in the predicted doses, there appears to be no set of conditions at JPG that would result in doses to occasional users in excess or even close to the 25 mrem y^{-1} limit. The predicted doses from modeling the resident farmer scenario range from 6.3 mrem y^{-1} to 62.5 mrem y^{-1} and depend on the K_d. Predicted doses ranged from 26.6 to 62.5 mrem y^{-1} when the smaller K_d value of 10 was used, and the range decreased to 6.3 mrem y^{-1} to 15.2 mrem y^{-1} when the K_d was 50. These values of K_d based on two literature determinations of an “average” or default K_d (K_d of 10 from NRC, 1998a, b; K_d of 50 from Yu et al., 1993a, b), and as defaults were considered best estimates of the range of values likely to be observed. The two ranges illustrate that uncertainty in a single parameter, in this case K_d, could greatly affect interpretations of the dose assessment data. Even with this large uncertainty, predicted doses from the Resident Farmer scenario are less than the 100 mrem y^{-1} limit and support release of the JPG lands for restricted use. Overall, then, risk assessments for the range of expected uses of JPG lands are within dose limits stipulated by the NRC for release for restricted use.

G. Conclusions

It is clear from the above analyses that the occasional user scenario, even when it includes hunting activity, results in doses to users well below the 25 mrem y^{-1} criteria for restricted release. Further, with careful administration of site access policies, the doses above should be considered the maximum doses to site users; in other words, site users would probably be exposed to even smaller doses than calculated.

The resident farmer scenario is not as certain to fall below the 100 mrem y^{-1} criterion for restricted release, however. The above results show that the predicted doses are less than the criterion, but alternative modeling conditions could be chosen so that the predicted doses fall outside the criteria. Those conditions that allow larger doses, however, would have to come from measurements of various parameters that affect the modeling as discussed above. Current uncertainty in the soil concentration and the K_ds, however, could be used to argue if the resident farmer scenario falls within the restricted release criteria. On the other hand, the use of a resident farmer scenario at all assumes that the custodian of the JPG lands will lose all ability to control access to the lands. While this is the “worst case scenario”, it is not realistic given the long history of military testing and the material that is left behind as a result of this necessary mission.

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Table 1. Descriptive statistics of DU concentrations in soil, groundwater, and surface water samples calculated from environmental monitoring samples collected 1984 through 2000.

	Soil ($pCi\ g^{-1}$)	**Groundwater ($pCi\ L^{-1}$)**	**Surface Water ($pCi\ L^{-1}$)**
Mean	18.8	2.7	1.6
Median	1.5	1.3	0.26
Standard Deviation	197.1	5.6	5.6
Minimum	-0.8	-0.1	-1.2
Maximum	3857	81.1	49
Number of Samples	388	365	312

Table 2. Pathways included in modeling scenarios. All food products are assumed to be produced on the farm.

	Scenario	
Pathway	**Occasional Use**	**Resident Farmer**
Drinking Water	No; off-site water brought in	Yes, potentially contaminated well
Soil Ingestion	Yes	Yes
Vegetable Ingestion	No; food from off-site	Yes
Meat Ingestion	*Visitor*: No *Hunter*: Yes, 10% of total Meat from hunting	Yes
Ingestion of Dairy Products	No; food from off-site	Yes
External Exposure	Yes	Yes
Dust from Interior of Buildings	No	Yes
Dust from Outside Air	Yes	Yes
Immersion in Water	No	Yes

Table 3. Values of source terms from previous risk assessment efforts and this report used for modeling at JPG.

Source Term (pCi g^{-1})	**Affected Area (m^2)**	**Reference**
8.6 or 35	3×10^6	Ebinger and Hansen, 1994 Abbott et al. (1983) U. S. Army, 1996
1.4 or 35	1.2×10^6 to 2.8×10^6	Ebinger and Hansen (1996a) SEG (1995, 1996) U. S. Army, 1996
91	1.5×10^6	Ebinger and Hansen (1996b) SEG (1995, 1996)
16 to 370, 90 average	5×10^5	Ebinger and Hansen (1998) SEG (1996)
35, 90	5×10^5	This Report

Table 4. Doses to resident farmer or occasional JPG user predicted using RESRAD 6.0. Peak doses (mrem y^{-1}) and time of peak dose (y, in parentheses) are shown.

	Resident Farmer (mrem y^{-1})	**Occasional User (mrem y^{-1})**
Soil Concentration: 35 pCi g^{-1}; Kd: 10 ml g^{-1}	26.6 (99.5)	1.6 (0)
Soil Concentration: 90 pCi g^{-1}; Kd: 10 ml g^{-1}	62.5 (99.5)	3.9 (0)
Soil Concentration: 35 pCi g^{-1}; Kd: 50 ml g^{-1}	6.3 (149)	1.7 (0)
Soil Concentration: 90 pCi g^{-1}; Kd: 50 ml g^{-1}	15.2 (149)	3.9 (0)

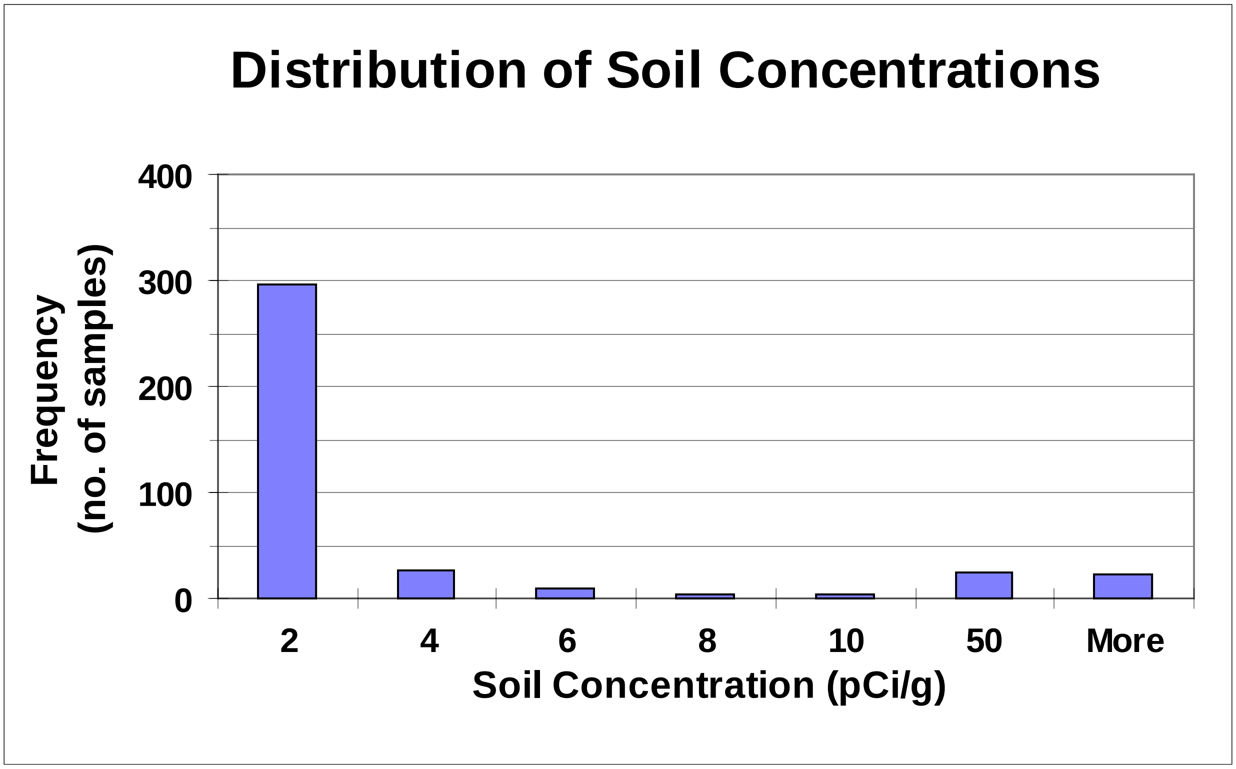

Figure 1. Frequency distribution of soil samples collected from 1984 through 2000. Label “More: refers to samples greater than 50 pCi/g.

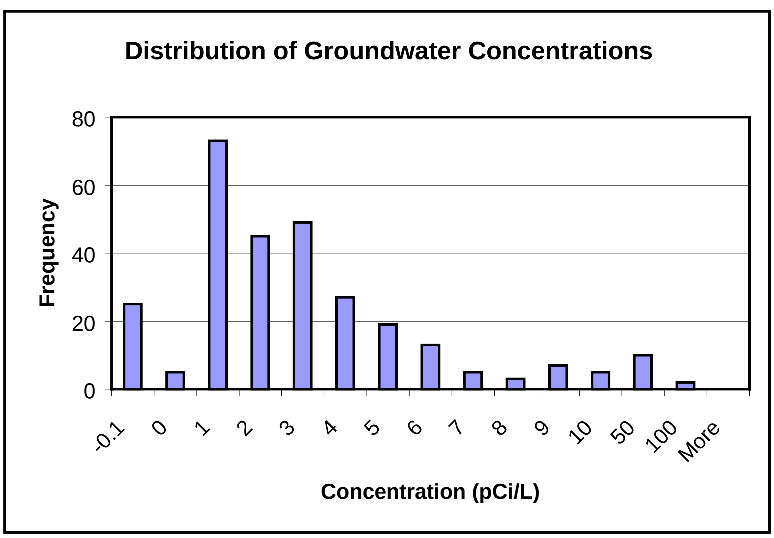

Figure 2. Frequency distribution of groundwater samples collected from 1984 through 2000.

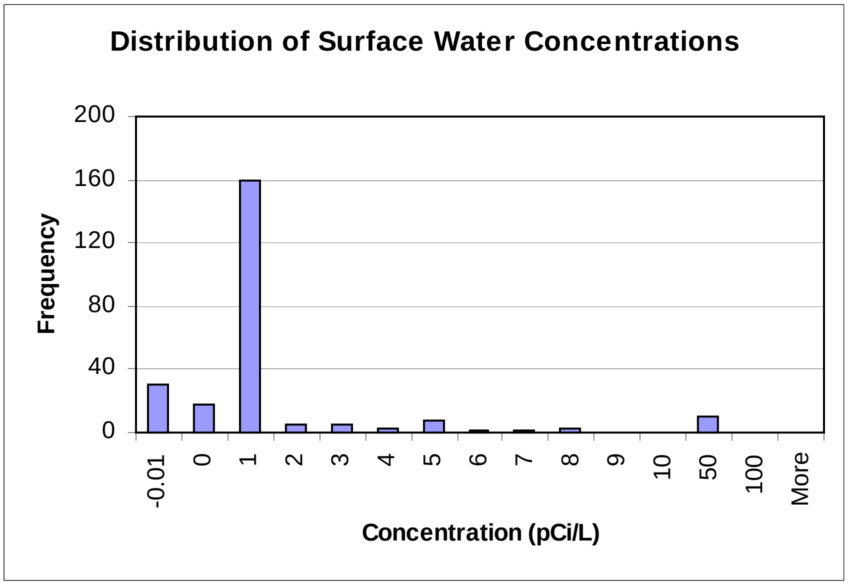

Figure 3. Frequency distribution of surface water samples collected from 1984 through 2000.

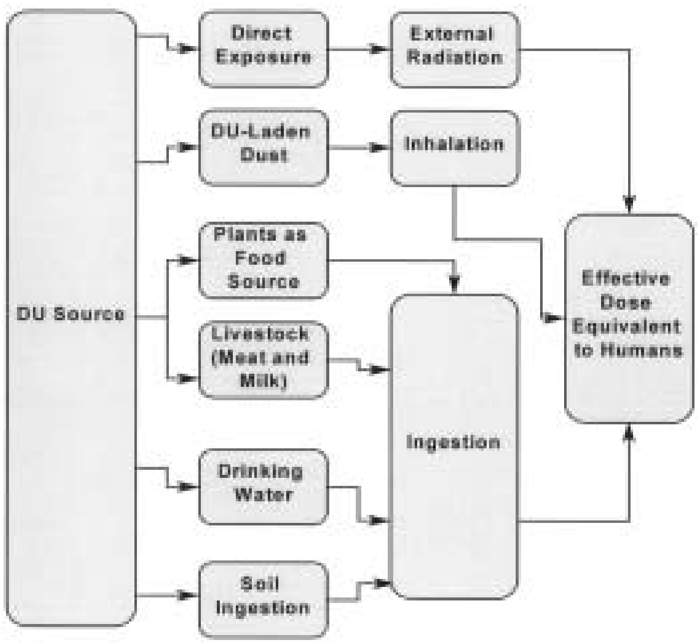

Figure 4. Conceptual model of DU transport through environmental compartments to humans (after Yu et al, 1993b).

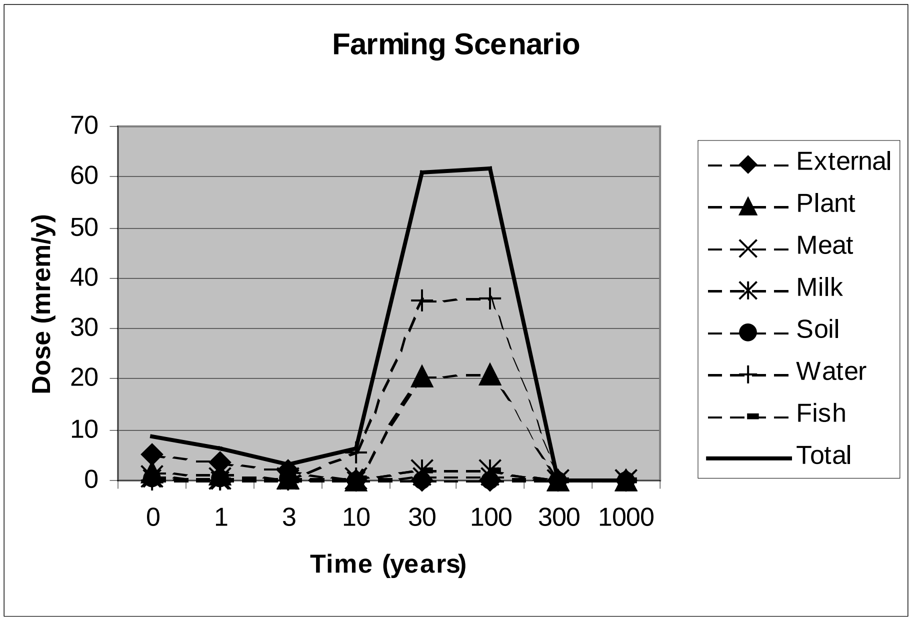

Figure 5. Dose vs. time graph for Resident Farmer scenario. Largest fraction of the dose is due to contaminated drinking water. Dose from inhalation is not shown for simplicity and was near zero throughout.

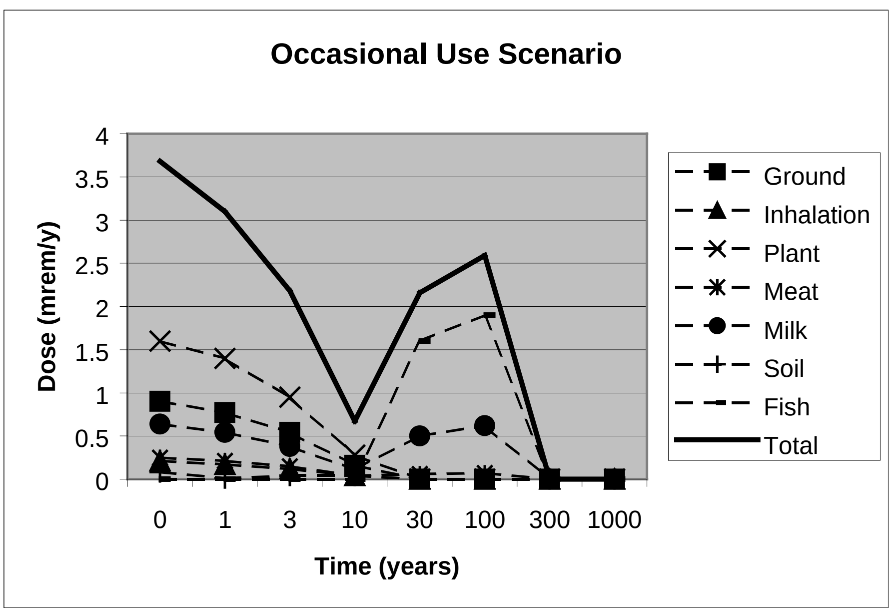

Figure 6. Dose vs. time graph for Occasional User scenario. Largest fractions of the dose were from external radiation and contaminated soil coatings on plant surfaces. Drinking water pathway not shown for simplicity and was zero throughout.

Appendix A. Comparison of NUREG 5512 (DandD) and RESRAD 6.0 defaults for this simulation.

	NUREG 5512	**RESRAD (Farming)**	**RESRAD (Occasional)**
Food Products	(kg/y)	(kg/y)	(kg/y)
Fruits, Vegetables, Grains	133.2	160	NA
Leafy Vegetables	21.4	14	NA
Roots	44.6		NA
Grain	14.4		NA
Beef	39.8	Calc. with poultry	NA
Poultry	25.3		NA
Beef and Poultry	65.1	63	63 (hunter)
Milk	233	92	NA
Fish	20.6	5.4	NA
Other Seafood	NA	0.9	NA
Exposure Parameters			
Inhalation rate (m^3/hr)	See below	0.96	0.96
Indoor inhalation rate (m^3/hr)	0.9	Uses single Inhalation Rate	Uses single Inhalation Rate
Outdoor inhalation rate (m^3/hr)	1.4	Uses single Inhalation Rate	Uses single Inhalation Rate
Gardening inhalation rate (m^3/hr)	1.7	Uses single Inhalation Rate	Uses single Inhalation Rate
Mass loading for outdoor inhalation (g/m^3)	3.14×10^{-6}	1×10^{-4}	1×10^{-4}
Mass loading, indoors (g/m^3)	1.4×10^{-6}	Uses single mass loading	Uses single mass loading
Mass loading, gardening (g/m^3)	4×10^{-4}	Uses single mass loading	Uses single mass loading
Mass loading, foliar deposition (g/m^3)	NA	1×10^{-4}	1×10^{-4}

Resuspension factor, indoor	2.8×10^{-6}	NA	NA
Floor dust loading (g/m^2)	1.6×10^{-1}	NA	NA
Dilution length, airborne dust (m)	NA	3	3
Exposure duration (y)	NA	30	30
Shielding Factor, Inhalation	NA	4×10^{-1}	4×10^{-1}
Shielding Factor, exte3rnal gamma	5.5×10^{-1}	7×10^{-1}	7×10^{-1}
Fraction of time spent outdoors	1.1×10^{-1}	2.5×10^{-1}	1×10^{-1}
Fraction of time spent indoors	6.6×10^{-1}	5×10^{-1}	0
Soil ingestion rate (g/y)	18.3	36.5	36.5
Drinking water intake (L/y)	478.5	510	0
Contamination fraction of drinking water	1	1	0
Contamination fraction of household water	1	1	NA
Contamination fraction of livestock water	1	1	1 (hunter)
Contamination fraction of aquatic food	1	1	NA
Contamination of plant food	1	1	NA
Contamination fraction of meat	1	1	1 (hunter)
Contamination fraction of milk	1	1	NA
Depth of soil mixing layer (m)	NA	.15	.15
Depth of roots (m)	NA	.9	.9
Drinking water fraction from groundwater	1	1	NA

Household water from groundwater	1	1	NA
Livestock water from groundwater	1	1	1 (hunter)
Irrigation fraction from groundwater	1	1	NA
Fraction of grain in beef diet	7.4×10^{-2}	0.8	NA
Fraction of grain in cow milk	3.1×10^{-2}	0.2	NA
Storage times for contaminated foods (d)			
Fruits, non-leafy veg. and grain	NA	14	NA
Leafy Vegetables	1	1	NA
Roots	14	NA	NA
Fruit	14	As above	NA
Grain	14	NA	NA
Milk	1	1	NA
Eggs	1	NA	NA
Meat and Poultry	As above	20	NA
Beef	20	As above	NA
Poultry	1	As above	NA
Fish	NA	7	NA
Crustacea and Mollusks	NA	7	NA
Well water	NA	1	NA
Surface Water	NA	1	NA
Livestock fodder	0	45	NA
Animal Intake Rates for Food, Water, Soil			
Fodder intake for meat (kg/d)	NA	68	68
Beef Forage (kg/d)	8.1	NA	NA
Grain for Beef (kg/d)	2.4	NA	NA
Hay for beef (kg/d)	16.3	NA	NA
Fodder for milk cow (kg/d)	35.2	55	NA

Hay for milk cow (kg/d)	26.1	NA	NA
Grain for milk cow (kg/d)	1.95	NA	NA
Poultry forage (kg/d)	5.6×10^{-2}	NA	NA
Poultry grain (kg/d)	6.3×10^{-2}	NA	NA
Layer Hen forage (kg/d)	7.5×10^{-2}	NA	NA
Layer Hen Grain (kg/d)	6.1×10^{-2}	NA	NA
Beef water (L/d)	50	50	50
Milk Cow water (L/d)	60	160	NA
Poultry water (L/d)	3×10^{-1}	NA	NA
Soil ingestion fraction, beef and milk cow	2×10^{-2}	NA	NA
Soil ingestion fraction, beef poultry and layer hen	1×10^{-1}	NA	NA
Soil ingestion, beef (kg/d)	NA	5×10^{-1}	5×10^{-1}
Bioaccumulation Factors (L/kg)	**Fish, NUREG 5512 (DandD)**	**Fish, RESRAD 6.0**	**Crustacea and Mollusks, RESRAD 6.0**
Pb	100	300	100
Ra	70	50	250
Th	100	100	500
U	50	10	60

Distribution Coefficients (ml/g)	**NUREG 5512 (DandD)**	**RESRAD 6.0**
Pb	2377	100
Ra	3529	70
Th	119	60000
U	2	50

Groundwater Pathway Parameters	**NUREG-5512 (DandD)**	**RESRAD 6.0**
Contaminated zone thickness (m)	0.15	0.15
Contaminated zone porosity	0.46	0.4
Contaminated zone effective porosity	NA	.2
Contaminated zone saturation	.17	Calculated
Contaminated zone bulk density (g/cm^3)	1.43	1.5
Unsaturated zone thickness (m)	1.2	1 (default = 4)
Number of unsaturated zone layers	1	Variable (1)
Unsaturated zone porosity	0.46	0.4
Unsaturated zone effective porosity	NA	.2
Unsaturated zone saturation	0.17	Calculated
Unsaturated zone bulk density (g/cm^3)	1.43	1.5
Irrigation rate	1.29 L/m^2-d	0.75 m/y
Contaminated zone erosion rate	NA	1×10^{-4} m/y
Annual Precipitation (m)	NA	1

APPENDIX F (Continued)

APPENDIX B: RESRAD Files for JPG Simulation

APPENDIX G

STATEMENT OF INTENT

DEPARTMENT OF THE ARMY
U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND
5183 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MARYLAND 21010-5424

REPLY TO ATTENTION OF

U.S. Nuclear Regulatory Commission
Washington, DC 20555

STATEMENT OF INTENT

As the Commander of the U.S. Army Soldier and Biological Chemical Command (SBCCOM) of Aberdeen Proving Ground, Maryland, and license holder and organization responsible for oversight, development and execution of the license termination process for the Jefferson Proving Ground (JPG), Madison, Indiana, I exercise express authority and responsibility to request from the Department of the Army adequate funds for decommissioning activities associated with operations authorized by U.S. Nuclear Regulatory Commission Material License No. SUB-1435. The authority and responsibility to request funds for JPG for this effort is established by the Permanent Orders 12-4 dated 12 January 1998 and Assumption of Command by Authority AR 600-20, Paragraph 2-3 dated 2 July 1998.

Within this authority, I intend to request funds be made available when necessary in the necessary amount for the maintenance and implementation of institutional controls necessary to support the license termination under the restricted release criteria for decommissioning the area known as the DU Impact Area located North of the firing line at JPG. I intend to request and obtain such funds sufficiently in advance of the need for implementation of any institutional controls by SBCCOM to prevent the lapse of these activities as required for JPG to insure compliance with the restricted release criteria as specified at 10 CFR 20-2403(b).

However, any requirement for this payment or obligation of funds established by this license termination plan shall be subject to the availability of funds, and no provision herein shall be interpreted to require payment of obligation of funds in violation of the Antideficiency Act, 31 United States Code Section 1341.

A copy of the Permanent Order 12-4 and the Assumption of Command by Authority is attached as evidence that I am authorized to represent SBCCOM in this transaction.

John C. Doesburg

JOHN C. DOESBURG
Major General, USA
Commanding
June 11, 2001

Attachment: As stated

DEPARTMENT OF THE ARMY
U.S. ARMY CHEMICAL AND BIOLOGICAL DEFENSE COMMAND
5222 FLEMMING ROAD
ABERDEEN PROVING GROUND, MARYLAND 21015-5423

REPLY TO
ATTENTION OF

AMSCB-CG 2 July 1998

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Assumption of Command by Authority AR 600-20. Paragraph 2-3

The undersigned assumes command of the U.S. Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Maryland 21010-5423 (W4MLAA) effective 2 July1991.

DISTRIBUTION:
Each CBDCOM Element

JOHN C. DOESBURG
Major General, USA
Commanding

Mike Smith

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY MATERIEL COMMAND
5001 EISENHOWER AVENUE, ALEXANDRIA,VA 22333-0001

PERMANENT ORDERS 12-4 12 January 1998

U.S. Army Soldier and Chemical Biological Command (SCBCOM)(Provisional), XA (W4MLAA), Aberdeen Proving Ground, MD 21010-5423

The following organization or unit action directed.

Action: Unit organized on a provisional basis.
Assigned to: U.S. Army Material Command (AMC), X2 (WOGWAA)
Mission: The mission SCBCOM is to develop, integrate, acquire, and sustain soldiers and related support systems to modernize, balance, and improve the soldier's warfighting capabilities, performance, and quality of life. Perform similar functions for other services and customers. To provide research, development and acquisition of nuclear, biological and chemical (NBC) equipment for U.S. Forces. Act as the Army NBC defense commodity command, to provide management of joint service NBC Defense material. To provide US chemical stockpile management and safe storage; prepare for and respond to chemical biological emergency events/accidents. Conduct remediation/restoration actions at chemical activities. To provide successful planning, management, and execution of treaty responsibilities. Provide demilitarization support.
Effective date: 15 January 1998
Military structure strength: NA
Military authorized strength: NA
Civilian structure strength: NA
Civilian authorized strength: NA
Accounting classification: NA
Authority: VOCG AMC
Additional instructions: a. These orders effect the provisional organization and realignment of The missions, functions and personnel from CBDCOM, XA (W4MLAA), GJ.A). (WIDGAA), WOLMAA), (WOMBAA), (WOMNAA), (WIFEAA), (W26FAA), (W38NAA), (W4UZAA), AMC Surety Field Activity, X3(W2EWAA) and Soldier Systems Command (SSCOM), XC (W038NAA), (WIDIAA).

b. Personnel will be detailed to the U.S. Army Soldier and Chemical Biological Command (Provisional) with baseline organizations responsible for the funding. CG, CBDCOM will assume operational control of the planning and transition process.

Permanent Orders 12-4 12 January 1998

c. Permanent personnel actions towards implementation will not be taken until HQ AMC/HQ DA has approved the U.S. Army Soldier and Chemical Biological Command (Provisional) for permanent organizations and all affected personnel are provided due process in accordance with OPM guidelines.

d. There will be no change in physical location. All personnel will remain in place.

e. UCMJ authority will remain with existing commanders.

Format: 740

FOR THE COMMANDER

Kathleen M. Barnes
KATHLEEN M. BARNES
Lieutenant Colonel, GS
Adjutant General

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1-Cdr, U.S. Army Training and Doctrine Command, ATTN : ATLOG-MAT-FM, Fort Monroe, VA 23561-7101 – Cdr. U.S. Army Management Analysis Agency, ATTN: MOFJ-SDC-A, Bldg 2588, Ft. Belvoir, VA 22060-5578
1-Cdr, U.S. Army Aviation and Missile Command: ATTN: AMSAM-RM-FD, Redstone Arsenal, AL 35815-5190
1-Cdr, U.S. Army Chemical and Biological Defense Command, Aberdeen Proving Ground, MD 21010-5423

APPENDIX H
RESTORATION ADVISORY BOARD MEETING SUMMARY

(NOTE 1: A RAB Meeting was conducted on 06 Feb 01. Verbatim minutes of all RAB meetings are provided to all RAB members and available in the JPG Administrative Record maintained at Hanover College, Hanover, IN.)

(NOTE 2: The information may be found on the JPG website. Refer to http://jpg.sbccom.army.mil).

APPENDIX I
JEFFERSON PROVING GROUND DU Summary Sheet

License Termination Standard Review Plan No. 26-MA-5970-01, Jefferson Proving Ground, Madison, IN, July 01
(NOTE: The following is a copy of the JPG DU Summary sheet provided to a Louisville radio station reporter. January 2001).

From 1941 to 1994, ordnance testing of conventional explosives was conducted at Jefferson Proving Ground (JPG). Beginning in 1984, JPG conducted accuracy test firing of tank penetrator rounds containing depleted uranium (DU) under a Nuclear Regulatory Commission (NRC) License, Number SUB-1435. This accuracy test firing took place north of the Firing Line at JPG and was a result of a research and development program to develop armor defeating kinetic energy weapons.

All munition test activities were terminated at JPG in 1994. In 1996, the NRC License Number SUB-1435 was amended to reflect termination of the testing activities and to allow possession only of DU in the area north of the Firing Line at JPG. In August 1999, the Army submitted a JPG Decommissioning Plan to the NRC to support license termination under the restricted release conditions found at 10 Code of Federal Regulations (CFR) 20.1403(b). In December 1999, the NRC determined that the JPG Decommissioning Plan was acceptable for technical review (64 Federal Register 70294, 16 December 1999).

At this time, the Army is in the process of revising the JPG Decommissioning Plan for the area north of the Firing Line. Within the 51,000 acres north of the Firing Line, there are an estimated 1.5 million rounds of unexploded ordnance (UXO) and a 2,000 acre area, known as the DU Impact Area, containing approximately 70,000 kilograms of DU. This revision is needed due to comments raised by Save the Valley (STV), Inc. on the 1999 plan and the issuance by the NRC of the Nuclear Material Safety and Safeguards (NMSS) Decommissioning Standard Review Plan (SRP), NUREG-1727, dated September 2000.

The decommissioning objective proposed by the Army for the JPG DU Impact Area is, restricted use governed by institutional controls. No DU remediation is planned at the site. The UXO, located in the same region as the DU, prohibits any DU remediation due to personnel safety and excessive cost reasons. Environmental monitoring will be continued until approval of the termination of the license. Upon the termination of License SUB-1435, environmental monitoring will cease and institutional controls will be implemented. The purpose of implementing Institutional Controls is to prevent or reduce risks to human health and the environment while all parties are using the area north of the Firing Line. These Institutional Controls will provide the necessary assurance that any person using the area north of the Firing Line will not be exposed to a level of radiation that would adversely affect their health. Note: The level of radiation exposure will not exceed 25 millirem per year.

Due to personnel safety concerns from UXO, no entity may conduct any demolition, excavation, digging, drilling, or other disturbance of the soil, ground, or groundwater, or use soil, ground, or groundwater for any purpose, in the DU area north of the Firing Line. This area is not to be used for residential purposes to include, but not limited to, housing, day care facilities, schools (excluding onsite employee training) and assisted living facilities.

A portion of the area north of the Firing Line is being used by the United States Fish and Wildlife Service (USFWS) as the Big Oaks National Wildlife Refuge in accordance with the National Wildlife Administration Act of 1966 as amended (16 U.S.C 688) and other applicable laws. The United States Air Force (USAF)/Indiana Air National Guard uses two smaller portions as bombing ranges.

The Army will retain ownership of the area north of the Firing Line. Range personnel and/or contractors will perform weekly inspections of the entire perimeter fence. The U.S. Army as licensee and deed title holder of the JPG site; USFWS and USAF/Indiana Air National Guard as caretakers; and county sheriffs and state law enforcement will cooperatively enforce general trespass, poaching, and other violations.

Public participation is encouraged throughout this license termination process. Information will be maintained and available at the Madison City Library in Madison, IN and the JPG Administrative Record at Hanover College Library in Hanover, IN.